Manual No. 14-6087-A
April 1968

# INSTRUCTION MANUAL

# FOR

# QSA SERIES

# WIDE-RANGE POWER SUPPLIES

## (MODELS 10-1.4, 10-2.2 and 10-3.7)

RAYTHEON COMPANY□SORENSEN OPERATION
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# SECTION I

# INTRODUCTION AND DESCRIPTION

1-1. INTRODUCTION.

1-2. This manual provides operation and maintenance instructions for the Models QSA 10-1.4, 10-2.2 and 10-3.7 power supplies, manufactured by Raytheon Company, Sorensen Operation.

1-3. The manual is divided into six sections. Section I contains a description of the units, as well as unit characteristic curves and a tabular listing of complete unit specifications. Details on initial inspections and checkout procedures are given in Section II. Operating instructions, including methods for adapting units to various applications, comprise Section III. Sections IV and V provide the principles of operation and maintenance procedures, respectively. A replacement parts list forms Section VI.

1-4. DESCRIPTION.

1-5. The units provide a highly regulated d-c output (0-10V) and are designed to accept any of three separate, single-phase a-c inputs. (For complete unit specifications, refer to Table 1-1.) They also offer extremely fast recovery times as well as characteristically low output impedances.

1-6. The wide selection of mounting positions is a unique feature. The units may be end, bottom or side mounted, using tapped holes in the enclosures. Finished with a black, baked-on, mar-resistant wrinkle coating, these enclosures serve not only as protective housings but also as heatsinks. This latter feature eliminates the need for an external heatsink.

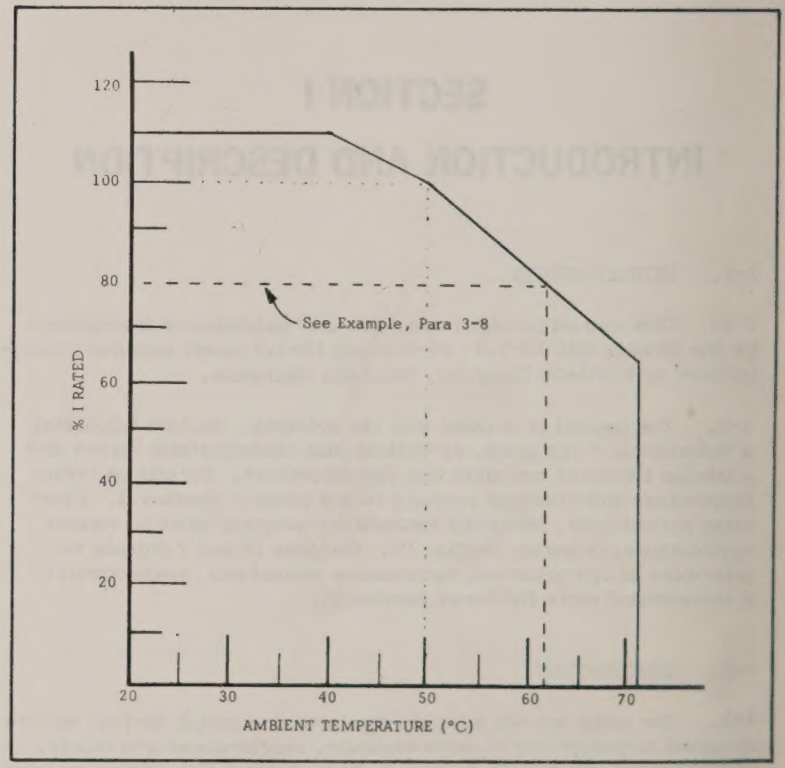



Figure 1-1. Current Derating

1-7. Operational features include remote sensing, programming, and series and parallel operation. In addition, each unit has a current-limiting system.

1-8. REMOTE SENSING. Provisions are incorporated in the unit for extending the output regulating point from the unit output terminals to

| | QSA MODELS | | |
|---|---|---|---|
| | 10-1.4 | 10-2.2 | 10-3.7 |
| Input Ratings | | | |
| Voltage ranges (Vac) | 105 - 125 / 200 - 240 / 210 - 250 | | |
| Frequency range (Hz) | 50 - 480 | | |
| Phase | 1 | | |
| Max. current (Aac) | | | |
| 115 Vac input | 0.6 | 0.8 | 1.4 |
| 230 Vac input | 0.3 | 0.4 | 0.7 |
| Power factor (typical)(1) | 0.84 | 0.83 | 0.83 |
| Efficiency (typical) (%)(1) | 29 | 35 | 39 |
| Output Ratings | | | |
| Voltage range (Vdc) | 0 - 10 | | |
| Resolution (typical) (mV) | 28 | | |
| Current range at 50°C(2) | 0 - 1.4 | 0 - 2.2 | 0 - 3.7 |
| Current Limit Characteristics | See Figure 1-2. | | |

(1) At nominal input and full rated output
(2) See Figure 1-1 for current derating characteristics

Table 1-1. Unit Specifications (Sheet 1 of 3)

| | QSA MODELS | | |
|---|---|---|---|
| | 10-1.4 | 10-2.2 | 10-3.7 |
| Regulation (3) | ± 0.005% or ± 0.2 mV (4) | | |
| Ripple Voltage (50-60 Hz)<br>RMS<br>Peak-to-Peak | <br>300 μV<br>3 mV | | |
| Transient Response (typical) (5) | 20 μs | | |
| Temperature Coefficient | 0.01%/°C or 0.5 mV/°C (4) | | |
| Output Voltage Turn-on and Turn-off Overshoots | None | | |
| Ambient Temperature Range | 0 - 71°C | | |
| Remote Programming<br>Resistance<br>Voltage Signal | <br>100 ± 0.5 ohms/volt<br>1 volt/volt | | |

(3) For combined load and line
(4) Whichever is greater
(5) For a step load change NL to FL, or FL to NL, and recovery to within a ± 10 mV band

Table 1-1. Unit Specifications (Sheet 2 of 3)

| | QSA MODELS | | |
|---|---|---|---|
| | 10-1.4 | 10-2.2 | 10-3.7 |
| Output Impedance | R + JωL | | |
| R (μ ohms) | 300 | 200 | 100 |
| L (μh) | 0.2 | 0.2 | 0.2 |
| Stability (6) | 0.025%/8 hours | | |
| Maximum Output - Series Connected System | 200 Vdc | | |
| Parallel Operation | See Para 3-26 | | |
| Remote Sensing Compensation (max) | 1.5 volts/load lead | | |
| Cooling | Convection | | |
| RFI Characteristics (typ) | Meets Mil-I-6181 and Mil-I-16910 | | |
| Envelope Dimensions (in.) | | | |
| Width | 3-7/8 | 5-1/8 | 5-1/8 |
| Height | 3-5/16 | 3-5/16 | 3-5/16 |
| Depth | 6-1/2 | 6-1/2 | 9-1/2 |
| Weight (lb) | 5 | 8 | 10 |

(6) 8 hours after warm-up and with constant load, line and ambient temperature

Table 1-1. Unit Specifications (Sheet 3 of 3)

the load. This feature, known as remote sensing, compensates for a maximum of 1.5 volts IR drop in each load line.

1-9. REMOTE PROGRAMMING. The unit is locally programmed, i.e., its output voltage is altered by rotation of the Output Adjust Control. To service those applications where it is desirable to maintain remote control over unit output, an arrangement for remote programming has been incorporated into unit design. This provision permits the introduction of a resistor (or a signal voltage) into the voltage adjust circuit to provide a precalculated output. Resistance-programming sensitivity is 100 $\pm$ 0.5 ohms/volts; sensitivity for voltage signal programming is a volt/volt. Refer to para 3-15.

1-10. SERIES OPERATION. For applications requiring output voltages higher than any single QSA can supply, a number of QSA units may be connected in series to provide a maximum output of 200 volts. Regulation in series operation is the sum of the regulations for all units. Refer to para 3-20.

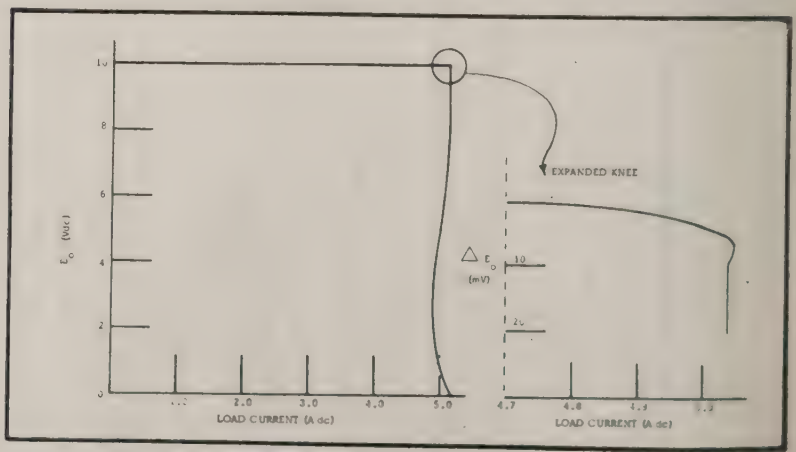



Figure 1-2. Current Limit Characteristic (typical)

1-11. PARALLEL OPERATION. Parallel operation may be used to service those applications requiring a higher output current than any single QSA can provide. Paralleling is indirect through a "master-slave" approach. The maximum number of units which may be paralleled is discussed in para 3-26.

1-12. CURRENT LIMIT. Overload and short-circuit protection is provided by a current-limit circuit which, in the event of an overcurrent condition, drops the unit output by abruptly increasing the impedance of the unit's passing stage.

1-13. OPTIONAL ACCESSORIES.

1-14. Two rack-mount adapters are offered as optional accessories to the QSA line. Designated SR1 and SR2, both are designed for standard 19-in. racks and both are only 3-1/2 in. in height. The SR1 accepts four QSA 10-1.4's or any other combination of three units. The SR2 will accept the same combinations as the SR1, but features a slide-type chassis and offers added versatility in that units may be mounted at adapter front and rear. Both adapters have screw-mounted face panels which enhance the appearance of any rack and which provide ready accessibility to the units if terminal-board alterations are required.

# SECTION II

# PREPARATION FOR USE

2-1. GENERAL.

2-2. After unpacking, initial inspections and preliminary checkout procedures should be performed to assure that unit is in good working order. Basically, these consist of visually checking for damaged parts and components, and of making an electrical check. If it is determined that the unit is damaged, follow the instructions on the Damage and/or Loss in Shipment form enclosed with the unit, and notify the carrier immediately. The carrier's claim agent will then prepare a report of damage. The user is required to send this report to the Service Dept., Raytheon Company, Sorensen Operation, Richards Avenue, Norwalk, Connecticut 06856. Sorensen will, in turn, advise the user as to what action is required to repair or replace the supply.

2-3. INSPECTION.

2-4. Check for damage incurred during shipment as follows:

a. Inspect enclosure for dents, chips, etc.

b. Check condition of external terminal board. Make certain that all screws are in place and that links are fitted over the barrier strips between the positive OUT terminal (1) and its adjacent SENSE terminal (2) and across the negative OUT terminal (4) and its adjacent SENSE terminal (3).

c. Using a slotted-drive screwdriver, rotate Output Adjust (adjust-access aperture located in nameplate) from stop-to-stop, and turn fully counterclockwise. Rotation should be smooth through a 300-degree angle.

d. Remove four screws retaining side enclosure plate, and inspect component board.

e. Remainder of enclosure may be removed by removing mounting screws and hex-head screws at nameplate end. Inspect transformer, capacitors and passing-stage transistors.

*Note*

A guide pin, located at closed end of enclosure, should be used to align enclosure and chassis when reassembling unit. Tighten cap screws to 25 lb-in.

## 2-5. INPUT CONNECTIONS.

2-6. If either of the two alternatives to a nominal 115-Vac input is to be used, change transformer T1 primary tap wiring as indicated in Figure 2-1. The factory-wired 115-Vac configuration is included to facilitate reconversion to this input, if such action becomes desirable at some future date. Remount enclosures following inspection or tap changing.

*Note*

Fuse the input if it is desired to protect the power transformer and rectifiers from excessive current caused by certain types of unit malfunction. Recommended fuse is Bussman Type 3AG or equivalent in the following sizes:

| Input | 10-1.4 | 10-2.2 | 10-3.7 |
|---|---|---|---|
| 115 Vac | 0.75 A | 1.0 A | 1.5 A |
| 220/230 Vac | 0.375 A | 0.5 A | 0.75 A |

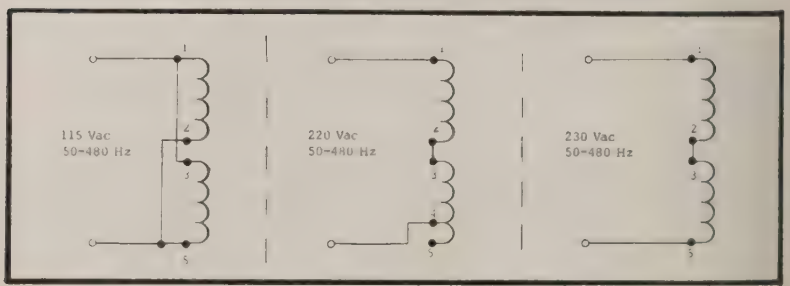



Figure 2-1. Input Connections

2-7. ELECTRICAL CHECK.

2-8. To perform an initial electrical check, proceed as follows:

a. Make certain unit is located in an area where free passage of air is unrestricted; then connect input leads to terminals 6 and 7 (IN) on unit terminal board. Use terminal 5 (GRD) for input system ground.

b. Connect a d-c voltmeter across terminals 1 and 4 (OUT). Select at least a 10 V-range.

c. Apply nominal input power.

d. Rotate Output Adjust from stop-to-stop. Voltmeter indicator should swing from 0 to 10 V.

e. Remove input power.

2-9. MOUNTING.

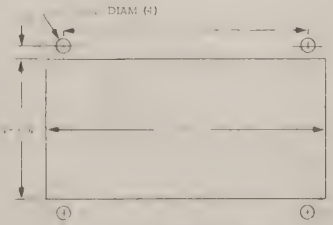
2-10. As previously mentioned, the units may be mounted in a variety of positions and locations, including a rack. Figure 2-2 illustrates the mounting-hole and knock-out dimensions for end, side and bottom mounting. Use No. 8-32 screws for mounting. In determining the length of screws to be used, consider washer and mounting-surface thickness and the 3/8 in. required for maximum thread engagement. When using nameplate-end mounting, place 1/4-in. spacers over mounting holes between unit and mounting surface.

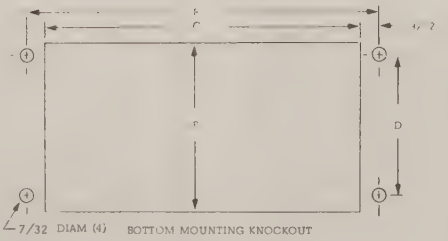
## CAUTION

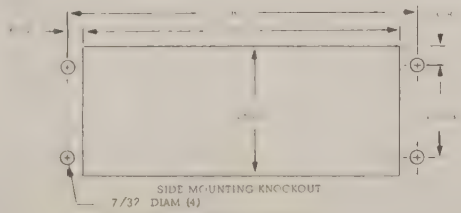
Knockouts are required for proper dissipation of heat generated by supply. Do not reduce knockout dimensions, nor impede natural flow of air around supply.

*Note*

If it is expected that unit will be subjected to shock or vibration during operation, do not use nameplate-end mounting.




NOTE: ALL DIMENSIONS ARE IN INCHES

DIMENSION CHART

| QSA SERIES | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| [illegible] | [illegible] | 5-11/16 | 5-1/8 | 2-3/8 | 2-7/8 | 3-5/8 |
| [illegible] | [illegible] | 5-11/16 | 5-1/8 | 3-5/8 | 4-3/8 | 4-5/8 |
| [illegible] | [illegible] | 8-11/16 | 8-1/8 | 3-5/8 | 4-3/8 | 4-5/8 |

Figure 2-2. Knockout Dimensions

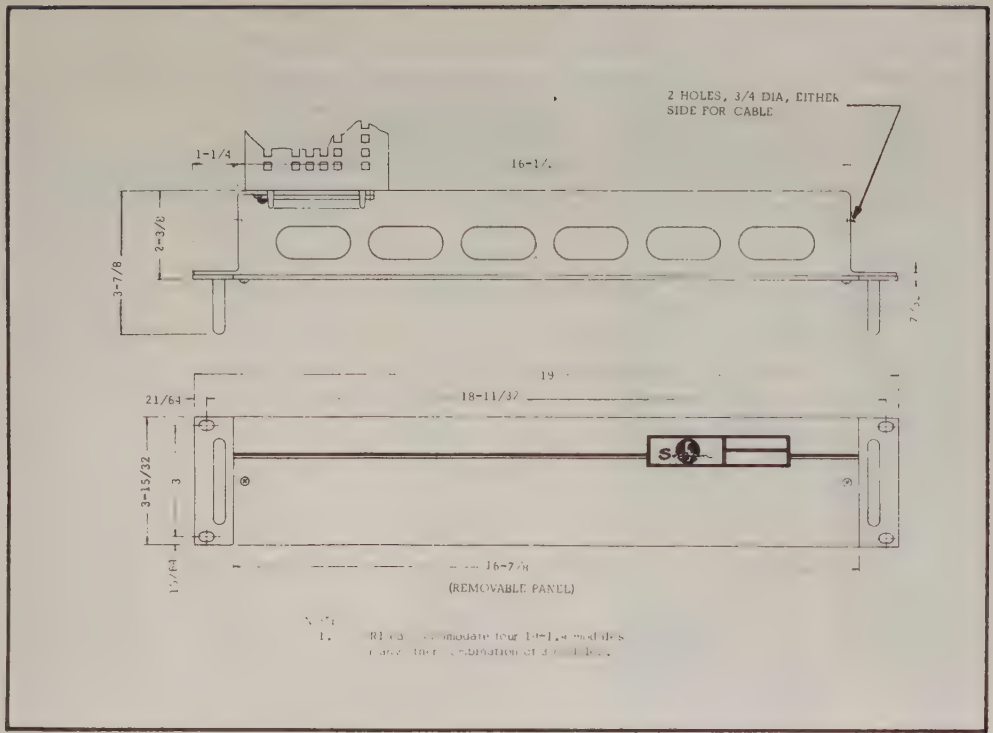



Figure 2-3. SR1 Rack Adapter

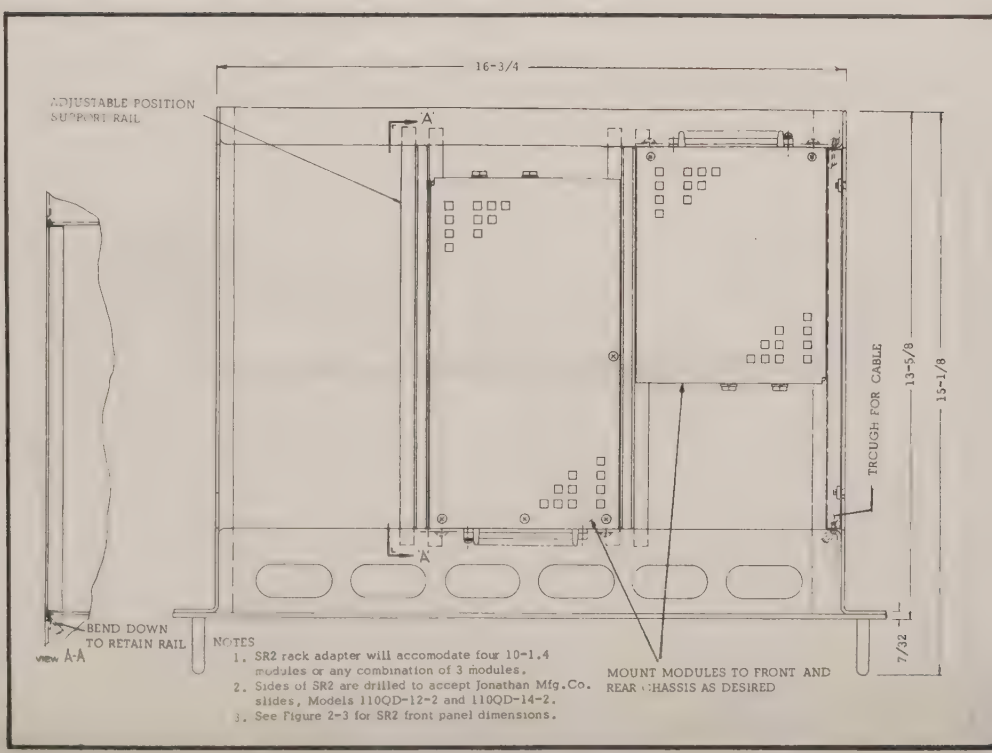

16-3/4
ADJUSTABLE POSITION SUPPORT RAIL
A
A
TROUGH FOR CABLE
13-5/8
15-1/8
7/32
BEND DOWN TO RETAIN RAIL
VIEW A-A
NOTES
1. SR2 rack adapter will accomodate four 10-1.4 modules or any combination of 3 modules.
2. Sides of SR2 are drilled to accept Jonathan Mfg.Co. slides, Models 110QD-12-2 and 110QD-14-2.
3. See Figure 2-3 for SR2 front panel dimensions.
MOUNT MODULES TO FRONT AND REAR CHASSIS AS DESIRED

Figure 2-4. SR2 Rack Adapter, Top View

2-11. If the units are to be rack mounted in the SR1 optional adapter (Figure 2-3), remove adapter face plate, position unit behind adapter and then secure with hardware enclosed in bag tied to adapter handle. Fit adapter to rack and attach. Make necessary input connections (para 2-5), check electrically per para 2-7, and adapt unit to desired application (Section III) before installing face panel.

2-12. If optional SR2 adapter is to be used for rack mounting, first insert tab ends of accompanying support rails into slots at front and rear chassis (see Figure 2-4). Then, bend tabs down to insure rigid retainment. Remove face panel, if units are to be mounted to front chassis. Next, place units on support rails and mount using hardware removed from bag tied to handle. Slide adapter into rack, attach, and then make necessary input connections (para 2-5), electrical checks (para 2-7) and output adjustment (Section III) before installing face panel.

# SECTION III
# OPERATING INSTRUCTIONS

3-1. GENERAL.

3-2. This section contains instructions on how to adapt the unit to, and operate it in, a number of varied applications. These include remote sensing, remote programming and series and parallel operation.

## CAUTION

The sensing and power circuits form a closed loop. Opening this loop, either by removing a terminal-board link or disconnecting a sensing or programming lead, will result in a high unit output and may damage the load or the supply.

3-3. CONTROLS.

3-4. QSA units are equipped with a single operating control, the Output Adjust potentiometer. This control is accessible through an aperture located in the nameplate end. Connected in series with the sensing network and across the output terminals, it is used to vary the unit output voltage.

3-5. PREOPERATION CONSIDERATIONS.

3-6. CURRENT-LIMIT TEMPERATURE COMPENSATION. As may be ascertained from Figure 1-1, current output is affected by the ambient temperature. The current-limiting value, on the other hand, is not so

affected. This means that, although the rated current output may well decrease due to high ambients, the current limit remains at its factory-set value (approximately 125% I rated at 50°C). In effect, this nullifies the protection which current limit is designed to provide. It is therefore recommended that, if the unit is to be operated in ambients between 40 and 71°C, the current limit be reset.

3-7. Compensation Calculation. The value to which the current limit should be reset may be determined as follows: measure the temperature of the environment in which unit will operate. Turn to Figure 1-1 and find this point along the abscissa (horizontal axis). Then extend a vertical line upward from the point until it intersects the slanted line. At intersection, extend a horizontal line to left until it meets the ordinate (vertical axis). The intersection here is the percentage of derating. Multiply this percentage by the maximum output current at 50°C (Table 1-1). Take the product obtained and multiply by 125%, or if a temperature-compensated setting is desired, by X%, where $X = 120 + \Delta T\ (0.2)$. (The $\Delta T\ (0.2)$ is a compensation factor for limit-circuit temperature sensitivity, where $\Delta T$ is the change in temperature and 0.2 the temperature coefficient. The "120" term compensates for the crossover and drift characteristics.)

3-8. Sample Calculation. For illustrative purposes, assume a Model QSA 10-2.2 is to be operated in an ambient of 62°C. From Figure 1-1, the derating percentage is found to be 80. The product of 0.80 and 2.2 is 1.76 A. This is the derated output. Next, multiply 1.76 A by 1.25. Current obtained is 2.2 A. For this example, 2.2 A would be used as the new current-limit value.

3-9. CURRENT-LIMIT RESET. To reset the current limit, proceed as follows:

a. Rotate Output Adjust fully clockwise.

b. Connect a d-c ammeter (0.5% tolerance) across the output terminals. Select a 0-10 A range on meter. The ammeter is to serve as an overload measuring instrument.

c. Remove side enclosure.

d. Apply nominal input power, and adjust potentiometer R6 on component board until ammeter indicates the compensated current-limit value.

e. Disconnect input power and test meter. Apply locking compound to R6, and remount enclosure.

3-10. LOCAL SENSING.

3-11. The unit is shipped ready for use in the local-sensing configuration. This means that the output is regulated at the output terminals, with no compensation for load-lead drops. If these drops are expected to be prohibitive, use the remote-sensing configuration as outlined in para 3-13.

3-12. To operate the unit, proceed as follows:

a. Connect a voltmeter across OUT (1 and 4) terminals.

b. Attach input leads to IN (6 and 7) terminals. Use GRD terminal (5) for input-system ground.

c. Apply nominal input power.

d. Rotate Output Adjust until desired output voltage is indicated on voltmeter.

e. Remove input power, disconnect voltmeter and connect load leads to terminals 1 and 4. Do not remove or loosen any of the interconnecting links. Apply nominal input. Unit supplies highly regulated power to load.

***WARNING***

Do not touch enclosure while unit is operating under load. Surface temperature is high. If unit must be handled immediately after operation, wear heat-resistant gloves.

3-13. REMOTE SENSING.

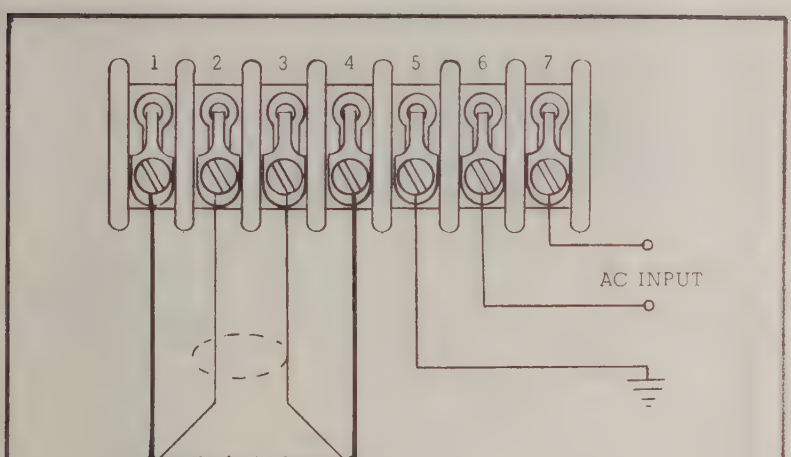



Figure 3-1. Remote Sensing

3-14. If it is desirable to sense (regulate) unit output at the load rather than at output terminals, remove links between the SENSE and OUT terminals. Using coaxial cable for the sensing leads, connect from SENSE terminals (2 and 3) to the load (see Figure 3-1), with the shield at the negative SENSE terminal (3). Put unit into operation per para 3-12. The unit's transient response degenerates slightly in remote-sensing operation. If this is an undesirable feature disconnect output capacitor C7 and reconnect it, or an identical capacitor, locally across the load. Rating of C7 may be determined from parts list in Section VI.

3-15. REMOTE PROGRAMMING.

3-16. RESISTANCE. The unit may be programmed to supply predetermined output voltages by inserting a calculated resistance into the programming circuit. In calculating the resistor's value, use the ratio

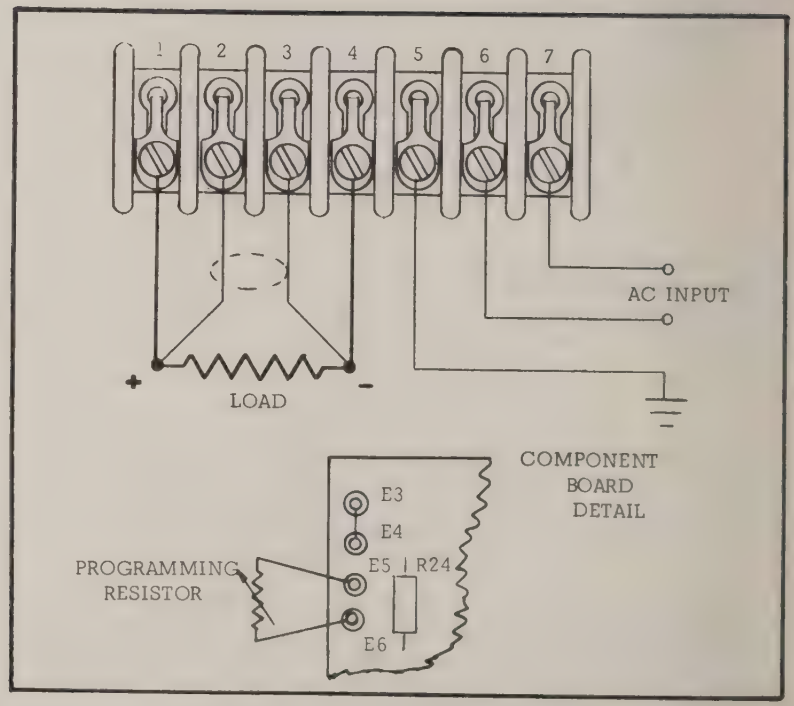



Figure 3-2. Remote Programming

of 100 ± 0.5 ohms/volt, i.e., for every volt of desired output between 0 and 10, about 100 ohms should be introduced into the programming circuit.

3-17. In selecting the resistor, make certain that it is a precision type with a low temperature coefficient (± 30 ppm/°C). Programming current is 10 mA. Choose a resistor with a wattage rating at least 10 times that calculated.

3-18. To adapt unit for external resistance programming, proceed as follows:

a. Remove side plate to expose component board.

b. Unsolder or cut jumper across terminal studs E5 and E6. (See Figure 3-2 for resistance programming hook-up.)

c. Insert precision resistor across studs. Use twisted or shielded wire for connecting leads, if any.

d. Remount side plate.

e. Turn Output Adjust fully counterclockwise.

f. Apply nominal input power, and verify that the output voltage across terminals 1 and 4 is the desired value.

g. Disconnect input power, make load connections and reapply input. Programmed output is now supplied to load.

*Note*

If programming is to be discontinued, remove input and reconnect jumper across studs E5 and E6.

3-19. VOLTAGE. The unit may also be programmed to supply a constant or variable output by introducing a voltage signal into the programming circuit. The procedure is identical to that for resistance programming (para 3-16), with this exception: instead of connecting a resistor across studs E5 and E6, connect the signal source. This source must be floating (not grounded) and the signal should have a low-noise, low-ripple content. In addition, it must be capable of absorbing the 10 mA programming current. For voltage-signal programming, the programming sensitivity is 1 volt-to-volt, i.e., the signal source must provide one volt of signal for each volt of desired output. Do not use a signal greater than 10 V.

3-20. SERIES OPERATION.

3-21. Any combination of 20 QSA Models may be connected in series to provide a cumulative output voltage of up to 200 volts. Maximum

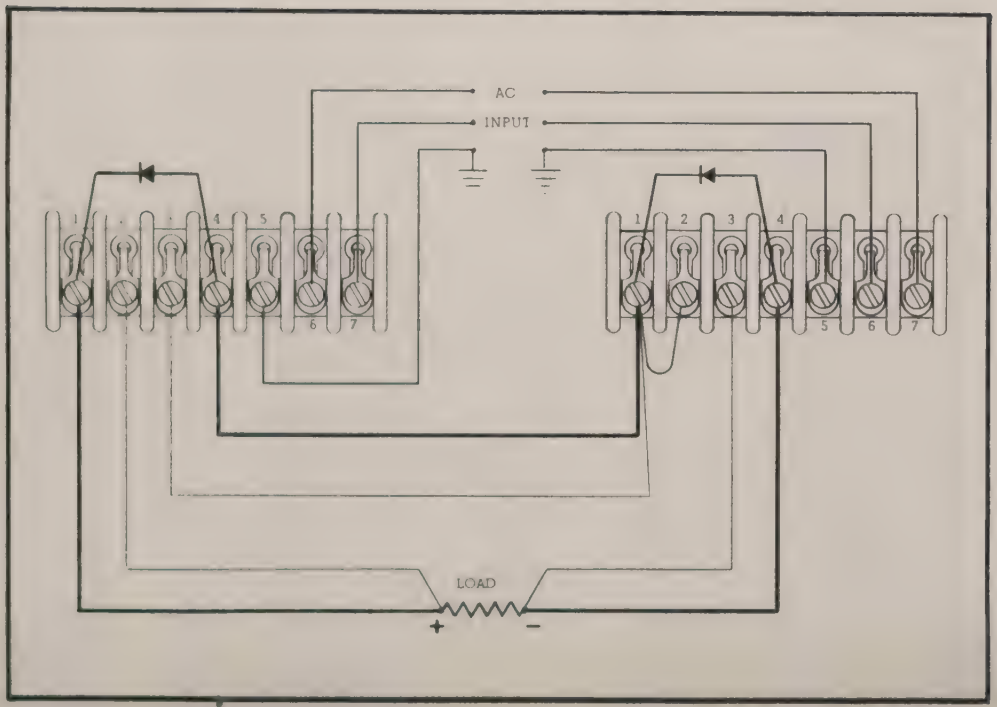



Figure 3-3. Series Operation

current output is limited to the output of the lowest rated supply. Total regulation is the sum of the regulations for all units.

3-22. If, in series operation, a unit fails, reverse voltage will appear across the failed unit's output terminals and consequently may damage the output capacitor. To clamp the reverse voltage to about 1 volt, connect a rectifier across each set of output terminals used in the system. Table 3-1 lists the rectifiers recommended for series operation.

3-23. To hook two units up in series, see Figure 3-3 and proceed as follows:

a. Remove links between the OUT (1 and 4) and SENSE (2 and 3) terminals on both units.

b. Connect an output lead from the positive OUT terminal (Unit 1) to positive side of load.

c. Run an output lead from the negative OUT terminal (Unit 2) to negative side of load.

d. Connect the negative OUT terminal (Unit 1) with positive OUT terminal (Unit 2).

e. Run sensing leads from positive SENSE terminal (Unit 1) and negative SENSE terminal (Unit 2) to load. Observe polarity.

f. Connect a sensing lead from the negative SENSE terminal (Unit 1) to positive OUT terminal (Unit 2). Next, using a sensing lead, connect the positive SENSE terminal (Unit 2) to the positive OUT terminal (Unit 2).

| QSA MODEL | MANUFACTURER | MFR PART NO. | SORENSEN PART NO. |
|---|---|---|---|
| 10-1.4 | Solitron | HC 67 | 26-1027-3 |
| 10-2.2 | Solitron | 2A15 | 26-1002-1 |
| 10-3.7 | Motorola | MR 1030A | 26-1006-1 |

Table 3-1. Rectifier Recommendations, Series Operation

3-24. PARALLEL OPERATION.

3-25. Loads which draw currents higher than a single unit's rated output may be serviced by paralleling units. Parallel operation is based on the "master-slave" concept, i.e., the "master" unit amplifier supplies drive current to all "slave" units. ("Slave" unit amplifiers are disconnected during the paralleling procedure.)

3-26. The number of units which may be paralleled using the "master-slave" approach is dependent upon the amount of current available to drive the "slave" unit passing stages. This current is a variable from unit-to-unit, and depends upon dissimilarities, within acceptable tolerances, in component characteristics. The maximum number of units which may be paralleled is therefore a function of the "master" unit selected and may vary anywhere from 4, in the worst case, to 15.

3-27. The following outlines the procedures for paralleling two units; however, the procedure need only be extended to parallel up to the maximum. Derate each unit to 90% of the maximum nominal output current. Maximum system output is the sum of the derated currents.

a. Apply input power to "master" unit, and adjust output voltage to desired value.

b. Remove input.

c. At internal component board of "slave" unit, disconnect, or cut, jumper across studs E1 and E2.

d. Interconnect stud E1 of the "slave unit and stud E1 of the "master" unit. (See Figure 3-4.)

e. Connect load leads from each unit to load. Observe polarity.

f. If desired, remote sensing may be employed by connecting sensing leads from SENSE terminals of "master" unit to the load terminals, again observing polarity.

g. Apply nominal input power to all units.

*Note*

System output will drop to zero if there is a discontinuity in input power to any unit, "master" or "slave".

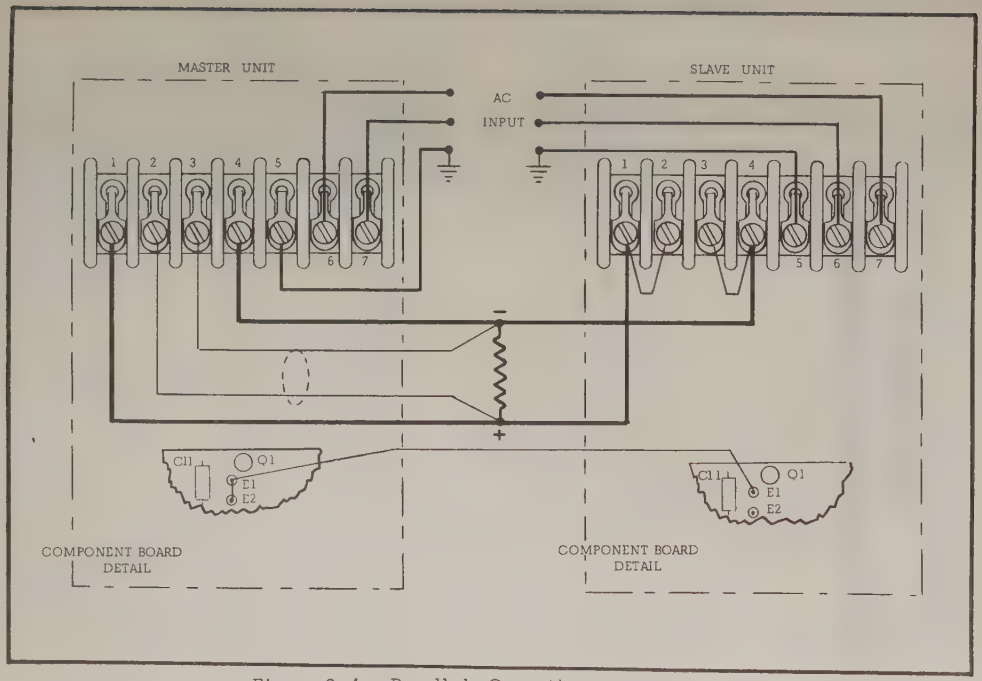



Figure 3-4. Parallel Operation

# SECTION IV
# PRINCIPLES OF OPERATION

## 4-1. GENERAL.

4-2. This section contains a description of the unit's basic operating principles, first in broad terms and then in more detail. Its function is to provide sufficient data which, when used in conjunction with the maintenance data and procedures outlined in Section V, will enable the user to logically and quickly isolate any unit malfunction.

## 4-3. PASSING-STAGE PRINCIPLE.

4-4. The QSA utilizes the series-passing-stage method of regulation. With this approach, a variable impedance absorbs the difference between the desired regulated output and filtered "brute-force" d-c. The variable impedance, to simplify this discussion, is assumed to be a single transistor (actually two are connected in parallel in the QSA 10-2.2 and 10-3.7 Models). Automatic regulation occurs when an output-derived error signal, fed back through amplifiers, is applied to the transistor, or passing stage, base. Figure 4-1 is an idealization, using input and output waveforms, of passing-stage operation.

## 4-5. BLOCK DIAGRAM.

4-6. The following brief description discusses unit operating principles in a general manner. A more detailed treatment is presented in subsequent paragraphs. Refer to Figure 4-2: the input transformer accepts an a-c input, steps down the voltage and applies it across a full-wave, center-tapped rectifier. Rectifier output is fed through a

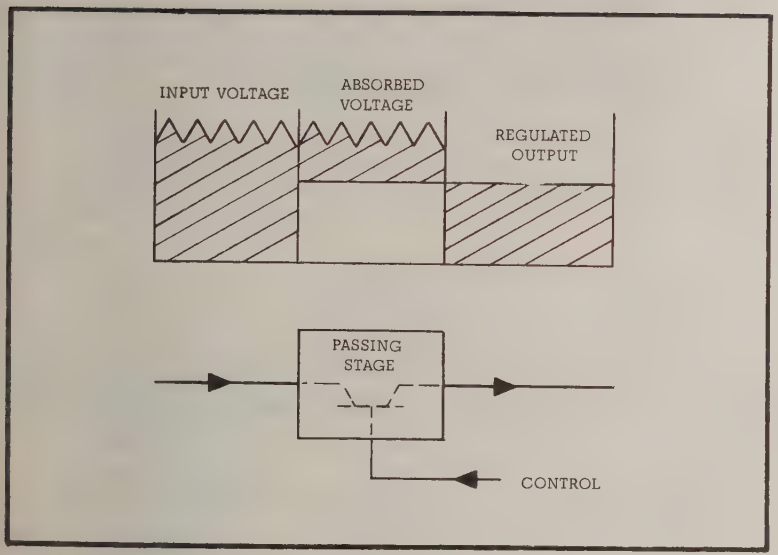



Figure 4-1. Series Passing Stage Principle

passing stage to the load. The passing stage acts to absorb the difference between the rectifier and desired output voltage. The feedback loop to the passing stage includes a sensing network which compares a sample of the unit's output against a fixed reference, provided by an internal reference power supply. Error signals resulting from the comparison are differentially amplified and fed to the drivers. These signals, then, are used to alter the impedance of the passing stage as a function of unit output. Short-circuit and overload protection is provided by the current-limiting section.

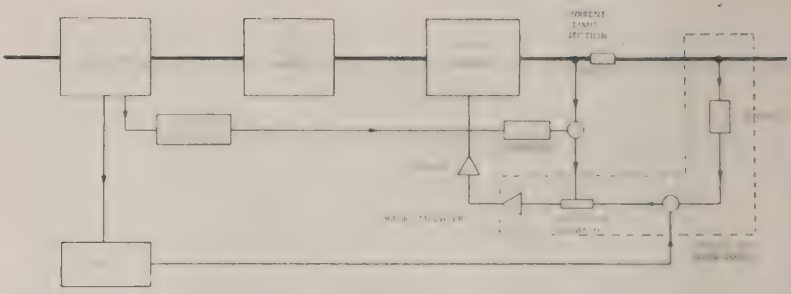


Figure 4-2. Block Diagram

## 4-7. DETAILED DISCUSSION.

4-8. REFERENCE POWER SUPPLY. The reference power supply provides 9 volts of highly stable, precise direct current as a reference for the sensing and error-amplifier circuit section. The supply derives its power from a full-wave, center-tapped rectifier (CR6 and CR7), connected across a secondary winding of T1. Basic supply components include transistor (Q5), two differential amplifiers (Q6, Q7 and Q8, Q9), zener diode (CR8) and potentiometer (R15).

*Note*

For schematic location of reference designations used throughout this section, see figure 5-3.

4-9. Reference-supply output voltage is sensed across potentiometer (R15), where a portion of the sample is compared with a voltage reference developed by zener (CR8). Resulting error signals are amplified and directed to the base of transistor (Q5). Q5 acts as a variable impedance, increasing or decreasing the voltage drop across the stage as a function of the output voltage.

4-10. As an illustration of circuit operation, assume that an increase in reference-supply output voltage is sensed across potentiometer (R15).

A portion of the sensed voltage is compared with the constant voltage developed across CR8. The resulting error signal forces Q9 into higher conduction. The current through Q9 increases, while that through Q8 decreases. (Resistor R16 acts as a current generator, pulling an approximately constant current that is the sum of the operating currents of Q8 and Q9.) Increasing current through Q9 brings about a decrease in drive current on the base of Q6. Operating current through Q6 drops, decreasing the drive to Q5. As a result, Q5 conducts less (impedance increases) and the voltage across R15 is regulated to the precise 9-volt output.

4-11. SENSING AND ERROR-AMPLIFIER SECTION. In this section, a comparison is made between the precise output from the previously described reference supply and a portion of the unit output voltage. Resulting error signals are differentially amplified and fed to the passing-stage section. Main components include output-adjust potentiometer (R18), resistor (R25), and differential amplifiers (Q12, Q13 and Q10, Q11).

4-12. As an illustrative example of circuit operation, assume that the output voltage starts to rise. The voltage across R18 increases and therefore the base of Q12 becomes more negative with respect to the base of Q13. The operating current through Q12 decreases, and the current in Q13 increases. (The increase results because the sum of the operating currents of Q12 and Q13 is held approximately constant by R24.) With a decrease of current through Q12, there is a decrease in drive on the base of Q10 (and an increase in base Q11 drive current.) Q10 therefore will go into a state of lower conduction, reducing the drive on Q1 and subsequently increasing the impedance of passing stage (Q2).

4-13. DRIVERS AND PASSING STAGE. The drivers and passing stage are comprised basically of two amplifiers (drivers) Q1 and Q3, and transistor Q2, connected in the positive output leg. Driver Q1 accepts a signal from differential amplifier (Q10, Q11), amplifies and then feeds it to the base of Q3. The signal is again amplified and directed to the base of Q2 where it determines Q2's conduction level, causing an increase or decrease in the absorbed voltage as a function of unit output.

4-14. CURRENT-LIMIT SECTION. The current-limit section operates to provide unit overload protection. If output current begins to increase above a preset value (determined by potentiometer R6), unit output voltage is rapidly decreased while the output current is held approximately constant. Main components include reference diode (CR5), resistors (R5 and R6) and transistor (Q4).

4-15. The section functions as follows: under normal conditions, transistor Q4 is nonconducting because of insufficient base-emitter voltage. However, as output current attempts to rise above the limiting value, the drop across R7 increases, as does the sum of the voltages across R6 and Q4 base-emitter. The voltage across R6 is held constant by CR5, and as a result, only Q4's base-emitter voltage increases. Q4 is then driven into conduction and draws current from differential amplifier (Q10,Q11). As may be recalled from para 4-12, this amplifier supplies the signal current to the drivers and passing stage, and it is this current which is rerouted. As a result, signal current to the drivers and passing stage is greatly diminished, and transistor Q2 approaches cut off. The output voltage drops as more voltage is absorbed by the passing stage and then stabilizes when the load condition is satisfied.

4-16. REVERSE-BIAS SECTION. The reverse-bias section functions (1) during "load-off" transients to improve the response time by rapidly cutting off the passing stage and (2) to absorb "thermal effect" current generated at high junction temperature. The section is made up of a full-wave, center-tapped rectifier (CR2, CR3), capacitor (C4), and resistors (R1, R2, and R3).

# SECTION V
# MAINTENANCE

5-1. GENERAL.

5-2. This section provides troubleshooting data, periodic servicing, and calibration and performance-testing procedures. The troubleshooting data should be used in conjunction with the schematic diagram (Figure 5-3), which tabulates voltage-check points, Section IV, which outlines the principles of operation, and Figures 5-1 and 5-2 which physically locate the parts appearing on the schematic. Any questions pertaining to repair should be directed to the nearest Sorensen representative (a list is included with the unit) or to the Service Department, Raytheon Company, Sorensen Operation, Richards Avenue, Norwalk, Connecticut 06856. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, authorization from the Sorensen Service Department must be obtained first. Raytheon Company will not assume responsibility for units returned without prior authorization.

5-3. PERIODIC SERVICING.

5-4. The QSA Models require no periodic servicing. However, it is recommended that, whenever a unit is taken off the line, the enclosure be inspected and cleaned of any accumulations of dust or other debris which could impede natural air flow through unit.

5-5. TROUBLESHOOTING.

| SYMPTOM | PROBABLE CAUSE |
|---|---|
| No Output | a. No input.<br>b. User-supplied fuse blown (check for shorted rectifier CR1, CR2, CR3, CR4, CR6 or CR7[1] or shorted transformer winding). |
| High Output | a. In reference supply, Q9, Q7, or CR8 open. Q8, Q6, or Q5 shorted. Defective R15.<br>b. Q1, Q3 or Q2 shorted [2].<br>c. In sensing and error-amplification section, Q10 or Q12 shorted, or Q11 or Q13 open. |
| Low or Negative Output | a. In reference supply, Q9, Q7 or CR8 shorted. Q8, Q6 or Q5 open.<br>b. Q1 or Q3 open.<br>c. In sensing and error-amplification section, Q10 or Q12 open, or Q11 or Q13 shorted.<br>d. In current limit section, Q4 or CR5 shorted. |
| Output Ripple Degenerates | CR1 or CR4 open. |
| Transient Response Degenerates | CR2 or CR3 open. |

(1) Complementary rectifier and transformer may be damaged.

(2) When replacing Q2, apply thermal junction compound to underside of transistor. Use Thermacote, Thermalloy Co., Dallas, Texas, or an equivalent.

Table 5-1. Troubleshooting Data

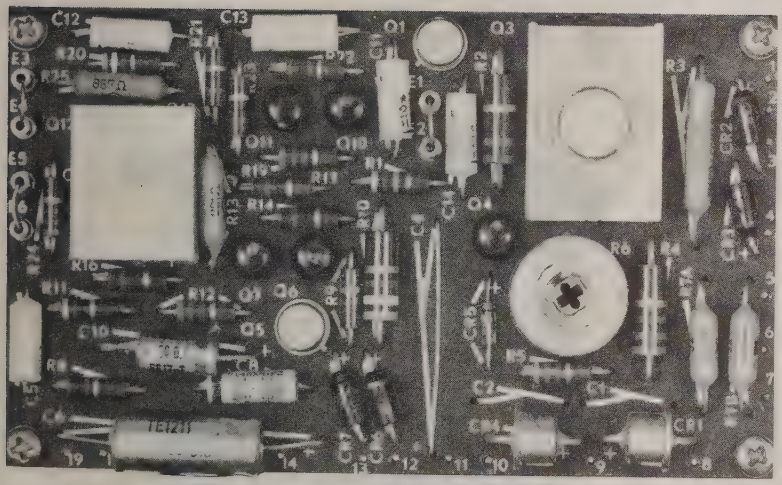



Figure 5-1. Typical Component Board (QSA 10-3.7 shown)

5-6. Table 5-1 lists a number of malfunction symptoms and their probable causes. The table covers symptoms which are attributed to a single component failure only. This should not be interpreted to mean that there could not be other causes for the tabulated symptoms. Multiple failures, for instance, may give identical indications. Footnotes in the table indicate which components may be damaged due to a "chain-reaction" effect. If any amplifier components are replaced, unit may require recalibration. Refer to para 5-7.

## 5-7. CALIBRATION.

5-8. To calibrate a QSA 10-V Model, proceed as follows:

a. Remove side enclosure.

b. Rotate Output Adjust (R18) fully clockwise. (Output Adjust shaft is accessible at aperture located in nameplate .)

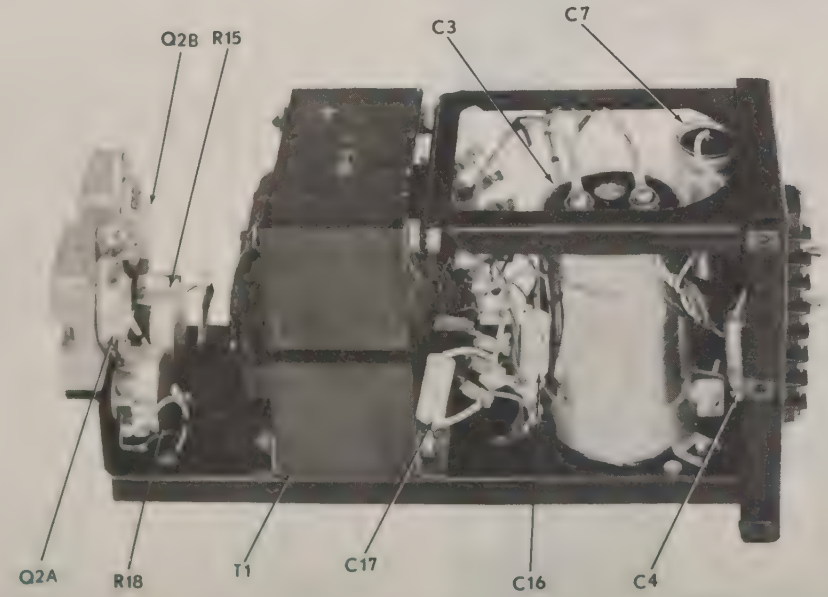



Figure 5-2. Partial Disassembly (typical)

c. Remove nameplate, and turn bridge-voltage adjust (R15) to center of rotation range. (R15's shaft is located directly above R18's when unit is in the normal position, i.e., with markings at terminal board right-side up.)

d. Rotate current-limit adjust (R6), located on component board, fully clockwise.

e. Remove jumper from across terminal studs E5 and E6 on component board, and then connect a precision-resistor box across studs. Set box resistance to exactly 1000 ohms.

f. Connect a sensitive 0-15 Vdc voltmeter across the OUT terminals on terminal board. At no load, apply nominal input to IN terminals.

g. Rotate bridge-voltage-adjust shaft (R15) to obtain a voltmeter indication of 10 $\pm$ .05 volts.

h. Remove input power, disconnect resistor box and reconnect jumper across studs E5 and E6. Reconnect input.

i. At no load and nominal line, turn Output Adjust (R18) from stop-to-stop. Test voltmeter should indicate a range of 0 to 10 volts.

j. With output set at 10 volts, disconnect input.

k. Using load leads, connect a 10 Adc meter across the OUT terminals.

l. Rotate current-limit adjust (R6) fully counterclockwise.

m. Apply nominal input, and rotate current-limit adjust (R6) to obtain an indication of 1.85 - 1.95 A (QSA 10-1.4), 2.9 - 3.0 A (QSA 10-2.2), or 4.9 - 5.1 A (QSA 10-3.7) on test ammeter.

n. Remove input. Disconnect test meters and resistance box. Apply locking compound to potentiometers R6 and R15.

## 5-9. PERFORMANCE TESTING.

5-10. OUTPUT RIPPLE. To measure output ripple, proceed as follows:

a. Connect a test set-up as shown in Figure 5-4. Set oscilloscope for 0.5 mV vertical and 10 ms/cm horizontal. (Oscilloscope should have at least a 30 MHz band width.) Select a 150-V range for a-c voltmeter. Choose a 0.5 mV range for RMS meter and a 5 A range for d-c ammeter. Use aresistive load with a current-drawing capacity

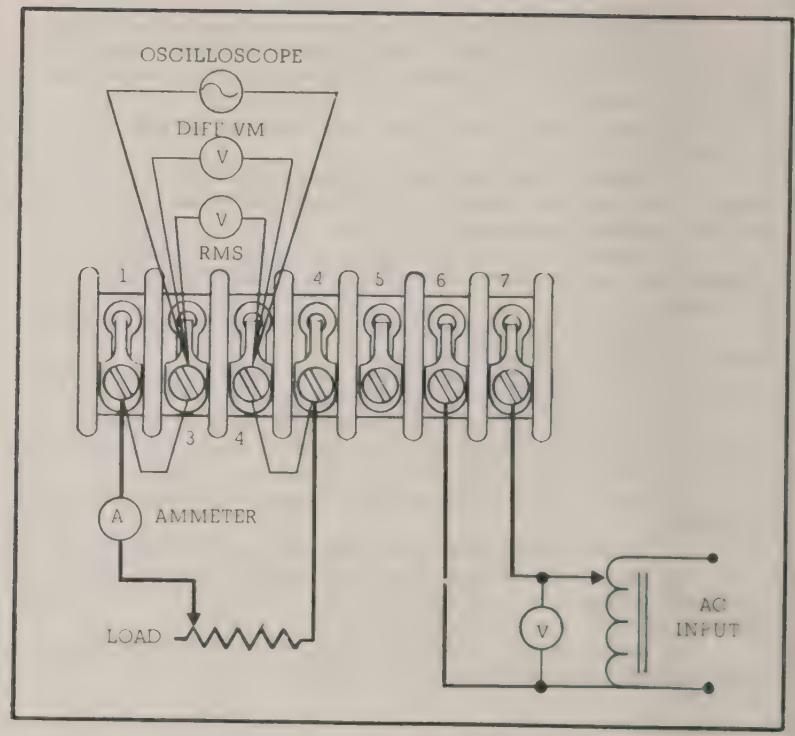



Figure 5-4. Performance Test Setup

of at least 5 A. Use the differential voltmeter as a VTVM. Select a 15-V range.

b. With no load, apply a 115 Vac, 60 Hz input, and adjust output to 10 V.

c. Apply full load and observe oscilloscope and RMS voltmeter. Voltmeter should indicate no more than 3.3 mV; oscilloscope should display a peak-to-peak voltage no greater than 3 mV.

d. If desired, check regulation per para 5-11.

5-11. REGULATION. To measure unit's output regulation, proceed as follows:

a. Connect unit to test set-up shown in Figure 5-4. The oscilloscope and RMS voltmeter are not necessary. Use the voltmeter in the differential mode. Select an internal voltage equal to 10 volts, and set null sensitivity to the 10 mV range.

b. Apply a 115 Vac, 60 Hz input, and adjust output voltage to obtain a null indication on voltmeter.

c. With a-c voltmeter indicating 115 Vac, increase load on unit until d-c ammeter reads 1.54 A (for the QSA 10-1.4), 2.4 A (for the QSA 10-2.2) or 4.0 A (for the QSA 10-3.7). Record the deviation from voltmeter null position.

d. Adjust voltmeter internal voltage to regain the null position. Then, with full load on unit, vary unit input voltage at 60 Hz from 105 to 125 Vac. Note the deviation.

e. Sum the deviations recorded in steps c and d. The total should be less than 1 mV.

# SECTION VI
# REPLACEMENT PARTS LIST

6-1. GENERAL.

6-2. This section provides a replacement parts list for the USA 10-V Models. The list is keyed to both the schematic diagram (Figure 5-3) and the parts-locating photographs (Figures 5-1 and 5-2).

6-3. MANUFACTURER CODING.

6-4. The column headed MANUFACTURER CODE contains a listing of letter designations which, when applied to the tabulations that follow, will give the manufacturer from whom a particular item may be purchased. The manufacturer's part number is listed in the MANUFACTURER PART No. column, the part may be ordered from the indicated manufacturer by using the Hosenson part number and a complete description of the item.

| | |
|---|---|
| AB | Allen Bradley Company |
| AX | Aerovox Corporation |
| CB | Centralab, Div. of Globe Union, Inc. |
| CTS | CTS Inc. |
| FC | Fairchild Semiconductor |
| IRC | International Resistance Co. |
| MA | Motorola Semiconductor Products |

| | |
|---|---|
| RCA | Radio Corporation of America |
| RT | Raytheon Company |
| SP | Sprague Electric Company |
| SR | Sorensen Operation, Raytheon Company |
| ST | Solitron Devices, Incorporated |
| WL | Ward Leonard Electric Company |

6-5. ORDERING PARTS.

6-6. When ordering parts from Raytheon Company, Sorensen Operation, include manufacturer's part number, the Sorensen part number and the unit model number. Address orders to:

Raytheon Company
Sorensen Operation
Richards Avenue
Norwalk, Connecticut 06856

| REF DES. | DESCRIPTION | SORENSEN PART NO. | MANUFACTURER | |
|---|---|---|---|---|
| | | | PART NO. | CODE |
| C1,2 | Cap., 4.7 nF, 200 Vdc | 24-2409-5 | | AX* |
| C3 | Cap., 1.4 mF, 25 Vdc | 24-2452-5 | | SP* |
| | Cap., 3.4 mF, 25 Vdc | 24-2544-2 | | SP≠ |
| | Cap., 6.7 mF, 30 Vdc | 24-2444-4 | | SP+ |
| C4 | Cap., 200 µF, 15 Vdc | 24-2278-17 | | SP |
| C5 | Cap., 4.7 nF, 200 Vdc | 24-2409-5 | | AX |
| C6 | Cap., 100 µF, 25 Vdc | 24-2279-14 | | SP |
| C7 | Cap., 650 µF, 25 Vdc | 24-2452-2 | | SP* |
| | Cap., 1 mF, 25 Vdc | 24-2452-4 | | SP≠ |
| | Cap., 2 mF, 20 Vdc | 24-2455-1 | | SP+ |
| C8 | Cap., 10 nF, 200 Vdc | 24-2409-7 | | AX |
| C9,13 | Cap., 22 nF, 200 Vdc | 24-2409-9 | | AX |
| C10 | Cap., 4 µF, 50 Vdc | 24-2280-4 | | SP |
| C11 | Cap., 2.2 nF, 200 Vdc | 24-2409-3 | | AX |
| C12 | Cap., 6.8 nF, 200 Vdc | 24-2409-6 | | AX |
| C14,15 | Cap., 15 nF, 200 Vdc | 24-2409-8 | | AX |
| C16,17 | Cap., 150 nF, 200 Vdc | 24-2409-14 | | AX+,≠ |
| C18 | Cap., 15 µF, 12 Vdc | 24-2276-9 | | SP |
| C19 | Cap., 10 nF, 50 V | 24-2014 | | CB |
| CR1,4 | Rectifier | 26-1027-4 | HC68 | ST* |
| | | 26-1006-2 | MR 1031A | MA≠,+ |
| CR2,3, 6,7 | Rectifier | 26-158-1 | CER 68 | ST |
| CR5,8 | Rectifier | 26-211 | 1N750A | MA |
| CR9 | Rectifier | 26-1006-1 | MR 1030A | MA≠,+ |

* Used on QSA Model 10-1.4 only.
≠ Used on QSA Model 10-2.2 only.
\+ Used on QSA Model 10-3.7 only.

Table 6-1. Replacement Parts List (Sheet 1 of 3)

| REF DES. | DESCRIPTION | SORENSEN PART NO. | MANUFACTURER PART NO. | MANUFACTURER CODE |
|---|---|---|---|---|
| Q1 | Transistor | 18-145 | RT 9343 | RT |
| Q2a | Transistor | 18-151 | 2N3055 | RCA |
| Q2b | Transistor | 18-151 | 2N3055 | RCA≠,+ |
| Q3 | Transistor | 18-142 | 40312 | RCA |
| Q4,6,7, 8,9,12, 13 | Transistor | 18-144 | FSC 3641 | FC |
| Q5 | Transistor | 18-146 | RT 9338 | RT |
| Q10,11 | Transistor | 18-143 | 2N3638 | FC |
| R1 | Res, 47k ohm, 1/2 W | 27-112 | EB 4731 | AB |
| R2 | Res, 1.8k ohm, 1/2 W | 28-729 | GB 1821 | AB |
| R3 | Res, 180 ohm, 5 W | 27-1521 | 5XM | WL |
| R4 | Res, 680 ohm, 1 W | 28-701 | GB 6811 | AB |
| R5,19,24 | Res, 680 ohm, 1/2 W | 27-156 | EB 6811 | AB |
| R6 | Pot., 400 ohm, 2 W | 29-489 | HC-110 | CTS |
| R7a | Res, 0.64 ohm, 3 W | 27-1517 | | WL* |
| | Res, 1.0 ohm, 3 W | 27-397-25 | | WL≠ |
| | Res, 0.47 ohm, 3 W | 27-1516 | | WL+ |
| R7b | Res, 1.0 ohm, 3 W | 27-397-25 | | WL≠ |
| | Res, 0.47 ohm, 3 W | 27-1516 | | WL+ |
| R8 | Res, 120 ohm, 1/2 W | 27-1107 | EB 1211 | AB |
| R9 | Res, 220 ohm, 1/2 W | 27-101 | EB 2211 | AB |
| R10 | Res, 390 ohm, 1 W | 28-703 | GB 3911 | AB |
| R11 | Res, 47 ohm, 1/2 W | 27-181 | EB 4701 | AB |
| R12 | Res, 820 ohm, 1/2 W | 27-182 | EB 8211 | AB |
| R13 | Res, 221 ohm, 1/2 W | 28-1188 | | IRC |

* Used on Model 10-1.4 only.
≠ Used on Model 10-2.2 only.
\+ Used on Model 10-3.7 only

Table 6-1. Replacement Parts List (Sheet 2 of 3)

| REF DES. | DESCRIPTION | SORENSEN PART NO. | MANUFACTURER PART NO. | MANUFACTURER CODE |
|---|---|---|---|---|
| R14,16, 17 | Res, 1.8k ohm, 1/2 W | 27-176 | EB 1821 | AB |
| R15 | Pot., 2k ohm, 4 W | 29-486 | | SR |
| R18 | Pot., 1.1k ohm, 4 W | 29-488 | | SR |
| R20 | Res, 390 ohm, 1/2 W | 27-1109 | EB 3911 | AB |
| R21,23 | Res, 2.7k ohm, 1/2 W | 29-174 | EB 2721 | AB |
| R22 | Res, 120 ohm, 1/2 W | 27-1107 | EB 1211 | AB |
| R25 | Res, 887 ohm, 1/2 W | 28-1216 | | IRC |
| R26 | Res, 0.2 ohms | 190-3636 | | SR |
| R30 | Res, 1k ohm, 1/4 W | 27-1305 | CB 1021 | AB |
| T1 | Transformer | 126-2889 | | SR* |
| | | 126-2890 | | SR≠ |
| | | 126-2891 | | SR+ |

* Used on Model 10-1.4 only.
≠ Used on Model 10-2.2 only.
\+ Used on Model 10-3.7 only.

Table 6-1. Replacement Parts List (Sheet 3 of 3)

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